

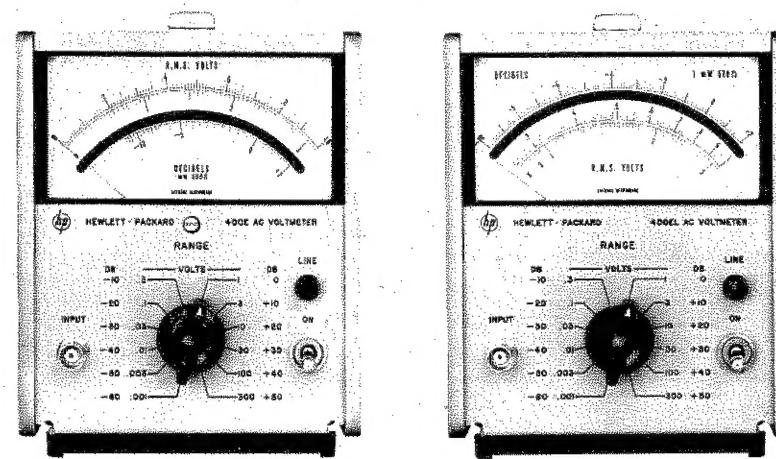
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OPERATING AND SERVICE MANUAL

HP 400E/400EL

# AC VOLTMETER

## 400E/400EL



HEWLETT  PACKARD

HP 400E/400EL



## **OPERATING AND SERVICE MANUAL**

-hp- PART NO. 00400-90006

### **MODELS 400E/400EL AC VOLTMETER**

**Serials Prefixed: 536-**

**Appendix C, Manual Backdating Changes,  
adapts manual to Serials Prefixed:  
536-04854 and below  
and 532-.**

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Table 1-1. Specifications

| Models 400E/400EL   |      |                  |  |                                   |                                  |  |  |  |
|---|------|------------------|--|-----------------------------------|----------------------------------|--|--|--|
| <b>Voltage Range:</b> 1mV full scale to 300V full scale in 12 ranges; dB scale -10 to +2dB, 10dB between ranges.  |      |                  | <b>Output Resistance:</b> 1000 ohms $\pm 5\%$<br><b>Response Time:</b> 1 second to within 1% of final value for a step change.   |                                   |                                  |  |  |  |
| <b>Frequency Range:</b> 10Hz to 10MHz.  |      |                  | <b>AC Power:</b> 115 or 230 volts $\pm 10\%$ , 50 to 400Hz, 5 watts.   |                                   |                                  |  |  |  |
| <b>Calibration:</b> Responds to absolute average value of applied signal, calibrated in rms volts.  |      |                  | <b>Temperature Range:</b> 0 to $+55^\circ \text{C}$ (except where noted on accuracy charts).   |                                   |                                  |  |  |  |
| <b>Input Impedance:</b> 10 megohms shunted by less than 25pF on the 1mV-1V ranges and 10 megohms shunted by less than 12pF on the 3V-300V ranges.                                       |      |                  | <b>External Battery Operation:</b> Terminals are provided on rear panel; positive and negative voltages between 35V and 55V are required, current drain from 50 to 75mA. |                                   |                                  |  |  |  |
| <b>Amplifier AC Output:</b> 150mV rms for full scale meter indication; output impedance 50 ohms, 10Hz to 10MHz (105mV on the 1mV range).<br><b>Accuracy:</b> $\pm 10\%$ , 10Hz to 4MHz. |      |                  | <b>Weight:</b><br>Net: 6 lbs. (2.7 kg).<br>Shipping: 8 lbs. (4 kg).  |                                   |                                  |  |  |  |
| <b>AC-DC Converter Output:</b> 1Vdc output for full scale meter deflection (linear output for Model 400E/EL).   |      |                  | <b>Dimensions:</b> 6-1/2 in. high, 5-1/8 in wide, 11 in deep (165, 1 X 130, 2 x 279, 4 mm).  |                                   |                                  |  |  |  |
| Models 400E/400EL   |      |                  |  |                                   |                                  |  |  |  |
| <b>ACCURACY: <math>\pm (\% \text{ full scale} + \% \text{ Reading})</math></b>  |      |                  |  |                                   |                                  |  |  |  |
| <b>3mV to 300V RANGES</b>   |      |                  |  |                                   |                                  |  |  |  |
| Frequency   | 10Hz | 40Hz             | 2MHz   | 4MHz                              | 10MHz                            |  |  |  |
|   |      | $\pm(2.5 + 2.5)$ | $\pm(1 + 0)$   | $\pm(1.5 + 1.5)$                  | $\pm(2.5 + 2.5)$                 |  |  |  |
| <b>1mV RANGE†</b>   |      |                  |  |                                   |                                  |  |  |  |
| Frequency   | 10Hz | 40Hz             | 500kHz   | 4MHz                              |                                  |  |  |  |
|   |      | $\pm(2.5 + 2.5)$ | $\pm(1 + 0)$   | $\pm(2.5 + 2.5)$                  |                                  |  |  |  |
| <b>AC-to-DC CONVERTER OUTPUT</b>  |      |                  |  |                                   |                                  |  |  |  |
| <b>3mV to 300V RANGES</b>   |      |                  |  |                                   |                                  |  |  |  |
| Frequency   | 10Hz | 20Hz             | 100Hz  | 500kHz                            | 1MHz                             |  |  |  |
|   |      | $\pm(2.5 + 2.5)$ | $\pm(1 + 1)$   | $\pm(\frac{1}{4} + \frac{1}{4})*$ | $\pm(\frac{1}{2} + \frac{1}{2})$ |  |  |  |
|   |      |                  |  |                                   | $\pm(2.5 + 2.5)$                 |  |  |  |
| <b>1mV RANGE†</b>   |      |                  |  |                                   |                                  |  |  |  |
| Frequency   | 10Hz | 20Hz             | 100Hz  | 100kHz                            | 1MHz                             |  |  |  |
|   |      | $\pm(2.5 + 2.5)$ | $\pm(1 + 1)$   | $\pm(0.4 + 0.1)*$                 | $\pm(1 + 1)$                     |  |  |  |
|   |      |                  |  |                                   | $\pm(2.5 + 2.5)$                 |  |  |  |

† From 1/3 full scale to full scale only.

\* For  $15^\circ \text{C}$  to  $40^\circ \text{C}$  on 1mV to 1 volt ranges only.

## SECTION I

### GENERAL INFORMATION

#### **1-1. DESCRIPTION.**

1-2. The -hp- Models 400E and 400EL are versatile ac voltmeters and dB meters. Both models can be used as ac to dc converters or wideband amplifiers. The Model 400E is primarily intended for voltage measurements, whereas the Model 400EL is primarily a dB meter. However, both meters indicate both volts and dB. The 400E has a linear ac scale with a logarithmic dB scale underneath, and the 400EL has a linear dB scale with a logarithmic ac scale underneath. Since the difference in scales is the only difference between the two instruments, this manual will use the term 400E/EL in reference to both instruments.

1-3. Figure 1-1 shows both the Model 400E and the Model 400EL. Table 1-1 is a list of specifications.

#### **1-4. OPTIONS AVAILABLE.**

#### **1-5. OPTION 01 (400E ONLY).**

1-6. Option 01 places the dB scale uppermost for greater resolution when making dB measurements.

#### **1-7. OPTION 02.**

1-8. Option 02 adds a relative reference adjustment to the 400E/EL. The REL. REF. control allows a continuous reduction in sensitivity by a maximum of 3 dB in order to make relative voltage or dB measurements.

#### **1-9. INSTRUMENT AND MANUAL IDENTIFICATION.**

1-10. Hewlett-Packard instruments are identified by a two-section, eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and Model 400E/EL described in this manual.

1-11. If a letter prefixes the serial number, the instrument was manufactured outside the United States.

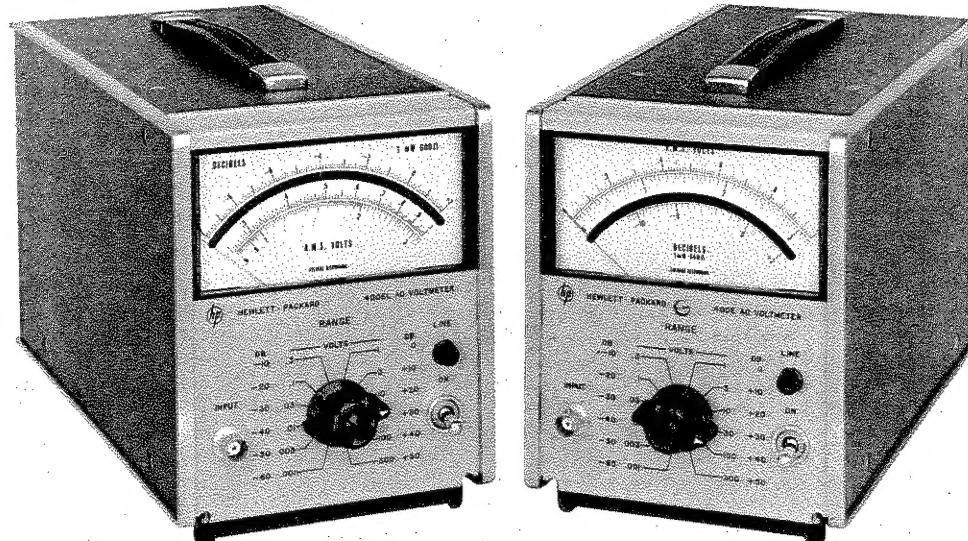


Figure 1-1. Models 400E and 400EL AC Voltmeters

## SECTION II

### INSTALLATION

#### **2-1. INTRODUCTION.**

2-2. This section contains information and instructions necessary for the installation and shipping of the Model 400E and 400EL voltmeters. Included are initial inspection procedures, power and grounding requirements, installation information, and instructions for repackaging for shipment.

#### **2-3. INITIAL INSPECTION.**

2-4. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in Paragraph 5-7. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

#### **2-5. POWER REQUIREMENTS.**

2-6. The Model 400E/EL can be operated from any source of 115 or 230 volts at 50 to 400Hz or from two 35 to 55 volt batteries connected to the rear panel BATTERY terminals. The 115/230V slide switch on the rear panel selects the desired line voltage. Power dissipation is 5 watts maximum.

#### **2-7. GROUNDING REQUIREMENTS.**

2-8. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-9. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

#### **2-10. INSTALLATION.**

2-11. The Model 400E/EL is fully transistorized; therefore, no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 55° C (131° F) or the relative humidity exceeds 95%.

#### **2-12. BENCH MOUNTING.**

2-13. The Model 400E/EL is shipped with plastic feet and tilt stand in place, ready for use as a bench instrument.

#### **2-14. INSTRUMENT CASE.**

2-15. The 400E/EL can be placed in a rugged, high impact plastic case (-hp- 11076A). The instrument can be operated, stored or carried in this splash-proof case. A dual purpose tilt stand also serves as a carrying handle. Storage space is located at the rear of the case and in the front lid.

#### **2-16. RACK MOUNTING.**

2-17. The Model 400E/EL may be rack mounted by using an adapter frame (-hp- Part No. 5060-0797). The adapter frame is a rack frame that accepts any combination of submodular units. It can be rack mounted only. For additional information, address inquiries to your -hp- Sales and Service Office. (See Appendix B for office locations.)

#### **2-18. COMBINATION MOUNTING.**

2-19. The Model 400E/EL may be mounted in combination with other submodular units by using a Combining Case (-hp- Model 1051A or 1052A). The Combining Case is a full-module unit which accepts various combinations of submodular units. Being a full-module unit, the combining case can be bench or rack mounted and is analogous to any full-module instrument.

#### **2-20. REPACKAGING FOR SHIPMENT.**

2-21. The following paragraphs contain a general guide for repackaging of the instrument for shipment. Refer to Paragraph 2-22 if the original container is to be used; 2-23 if it is not. If you have any questions,

contact your local -hp- Sales and Service Office. (See Appendix B for office locations.)

**NOTE**

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number, serial number, and serial number prefix.

2-22. If original container is to be used, proceed as follows:

- a. Place instrument in original container if available. If original container is not available, a suitable container can be

purchased from your nearest -hp- Sales and Service Office.

- b. Ensure that container is well sealed with strong tape or metal bands.

2-23. If original container is not to be used, proceed as follows:

- a. Wrap instrument in heavy paper or plastic before placing in an inner container.
- b. Place packing material around all sides of instrument and protect panel face with cardboard strips.
- c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.
- d. Mark shipping container with "DELICATE INSTRUMENT," "FRAGILE" etc.

## SECTION III

### OPERATING INSTRUCTIONS

#### **3-1. INTRODUCTION.**

3-2. The Model 400E/EL is primarily an ac voltmeter and dB meter, but it can be used as an ac to dc converter or as a wide band amplifier.

3-3. This section explains the controls of the 400E/EL and outlines the operating procedures for each mode of operation.

#### **3-4. LOCATION OF CONTROLS AND INDICATORS.**

3-5. Figure 3-2 shows the location of each of the 400E/EL controls and explains the function of each.

#### **3-6. OPERATING INSTRUCTIONS.**

#### **3-7. STANDARD 400E/EL.**

#### **3-8. Ac Voltmeter.**

Table 3-1. Effect of Distortion on Average Responding Meter

| Harmonic | % Distortion | % ERROR<br>(* Fundamental) |                  |
|----------|--------------|----------------------------|------------------|
|          |              | Max.<br>Positive           | Max.<br>Negative |
| Any even | 0.1          | 0.000                      |                  |
|          | 0.5          | 0.001                      |                  |
|          | 1.0          | 0.005                      |                  |
|          | 2.0          | 0.020                      |                  |
| Third    | 0.1          | 0.033                      | 0.003            |
|          | 0.5          | 0.168                      | 0.167            |
|          | 1.0          | 0.338                      | 0.328            |
|          | 2.0          | 0.687                      | 0.667            |
| Fifth    | 0.1          | 0.020                      | 0.020            |
|          | 0.5          | 0.101                      | 0.099            |
|          | 1.0          | 0.205                      | 0.195            |
|          | 2.0          | 0.420                      | 1.380            |

\* Depends on phase relationship between harmonic and fundamental.

#### **NOTE**

Since the 400E/EL is average responding and rms calibrated, any distortion will affect the accuracy of the measurement. Table 3-1 shows the errors caused by distortion.

- a. Ensure that 115-230 vac slide switch on the rear panel matches line voltage used, and connect power to the instrument. Mechanically zero the instrument using the procedure outlined in Paragraph 5-5.
- b. To operate the Model 400E/EL with battery power, connect two 35 to 55 volt batteries as shown in Figure 3-1. Since the front panel LINE switch has no effect during battery operation, the switch in Figure 3-2 can be used as a convenient method of disconnecting the batteries when the instrument is not in use. Two 35 volt batteries will draw approximately 75mA and two 55 volt batteries will draw approximately 50mA.

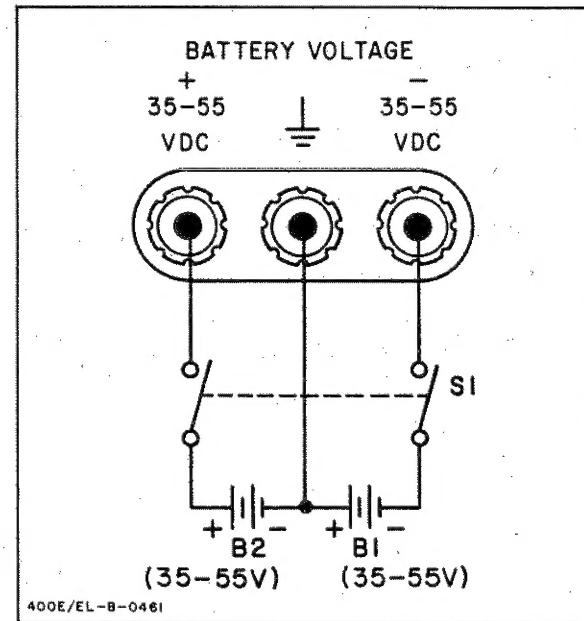


Figure 3-1. External Battery Connection

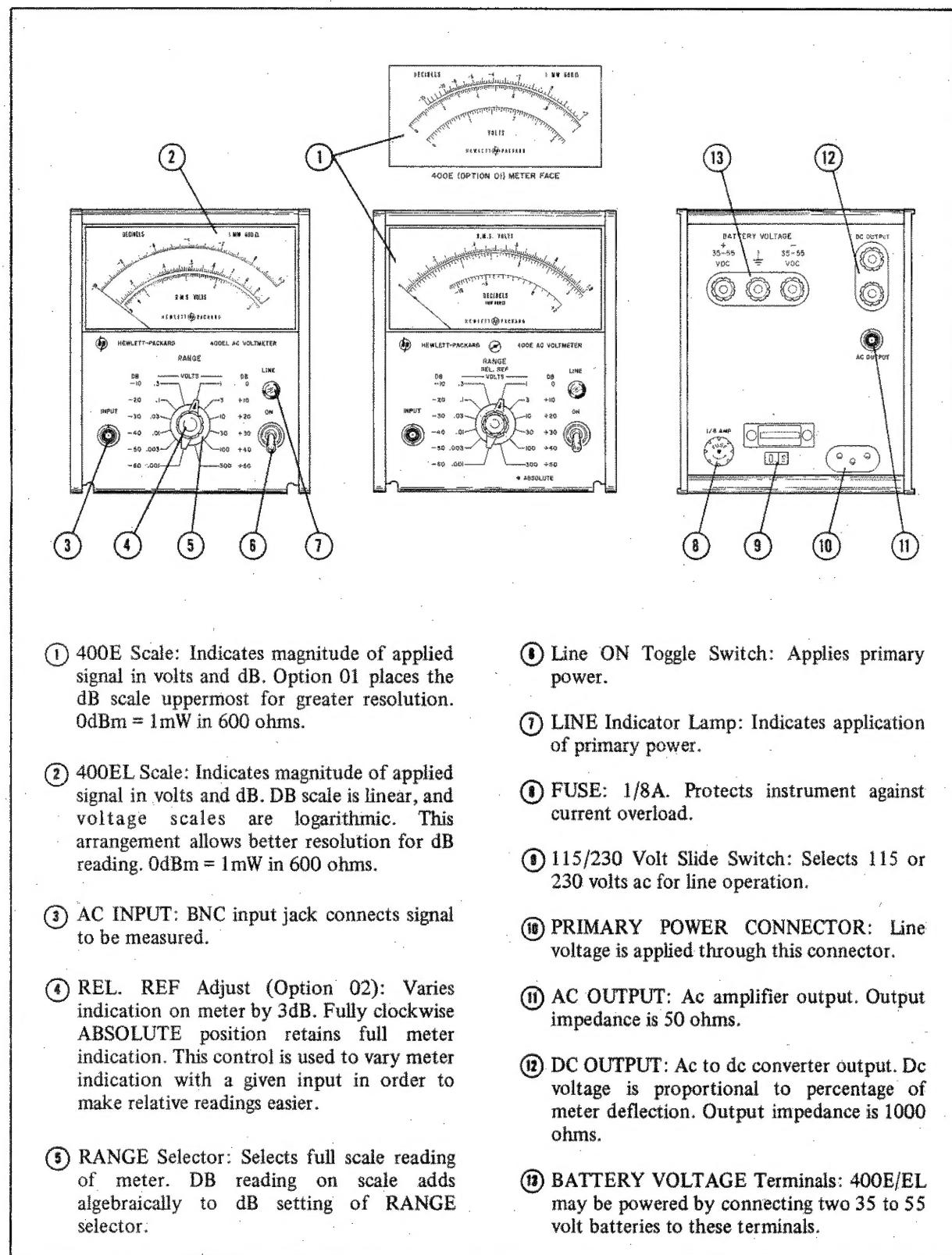


Figure 3-2. Location of Controls and Indicators

- c. Turn line ON toggle switch to up position. LINE lamp will glow.
- d. Select approximate range of signal to be measured.



**CAUTION**

DO NOT APPLY MORE THAN 600 VOLTS TO INPUT. DO NOT OVERLOAD THE .001 THROUGH 1 VOLT RANGES WITH MORE THAN 300 VOLTS AT FREQUENCIES BELOW 300kHz OR WITH MORE THAN 64 VOLTS AT FREQUENCIES ABOVE 300kHz. IF ANY OF THESE OVERLOADS ARE EXCEEDED, THE INSTRUMENT MAY BE DAMAGED.

- e. Connect signal to be measured to INPUT terminals, and read the rms voltage on the scale.

### 3-9. DB Meter.

- a. To make a dB or dBm measurement, follow steps a through e in Paragraph 3-8, and add the scale reading to the RANGE setting. For example: If the scale reading is +1.5 and the RANGE is -30dB, the final measurement is -28.5dB.
- b. The 400E/EL dB scale is calibrated in dBm. 0dBm is equivalent to 1 milliwatt dissipated by a 600 ohm load. Consequently, any dBm measurements must be made across a total impedance of 600 ohms. Measurements across other impedances will be in dB, but not dBm.
- c. To convert a dB reading to dBm, use the Impedance Correction Graph (Figure 3-3). For example: To convert a +30dB reading made across 50 ohms to dBm, locate the load impedance on the bottom of the graph. Follow the impedance line to the heavy black line and read the meter correction at that point. The correction for 50 ohms is +10.5dBm, and the corrected reading is +40.5dBm.

### 3-10. Ac to Dc Converter.

- a. Follow steps a through e in Paragraph 3-8.

- b. Connect the rear panel DC OUTPUT terminals to a dc measuring device with a high input impedance. The dc output resistance is 1000 ohms; and if it is loaded, the dc output signal will be inaccurate.

- c. The dc output is a 0 to 1 volt signal proportional to the percentage of 400E/EL meter deflection.

### 3-11. Wide Band Ac Amplifier.

- a. Follow turn-on steps a through c in Paragraph 3-8.
- b. Select approximate range of input on RANGE switch.
- c. Connect SIGNAL to be amplified to INPUT terminals.
- d. When using the ac power source, prevent ground loops by using a NEMA adapter on the oscilloscope, counter or other instrument used with the 400E/EL. Keep leads as short as possible and shield the input of the ac voltmeter to minimize pick-up.

#### NOTE

Place a 1 kilohm shielded load across the DC OUTPUT, if it is not being used, when using the AC OUTPUT. This is especially necessary on low ranges.

- e. The gain of the amplifier depends on the RANGE selection. On the 0.1 volt range and below, the 400E/EL amplifies the input; and on the 0.3 volt range and above, it attenuates the input. On the 0.001 volt ranges, the maximum output is 105mV. On all other ranges, the maximum output is 150mV. Table 3-2 shows the ac amplifier gain for each range setting.

Table 3-2. AC Amplifier Gain

| RANGE | GAIN  | RANGE | GAIN  |
|-------|-------|-------|-------|
| 0.001 | +40dB | 1     | -16dB |
| 0.003 | +34dB | 3     | -26dB |
| 0.01  | +24dB | 10    | -36dB |
| 0.03  | +14dB | 30    | -46dB |
| 0.1   | +4dB  | 100   | -56dB |
| 0.3   | -6dB  | 300   | -66dB |

**3-12. 400E WITH OPTION 01.**

3-13. Operation of the 400E with Option 01 is essentially the same as operation of the standard 400E; The dB scale reads from -15 to +2 instead of from -12 to +2, and is placed at the top of the scale for better resolution.

**3-14. 400E/EL WITH OPTION 02.**

3-15. Option 02 adds a relative reference adjustment

to the 400E/EL. This adjustment allows a meter indication to be varied by 3dB. Use the REL. REF adjustment to set the meter at any convenient reference (0dB for example) in order to make relative readings easier. When the REL. REF adjustment is in the fully clockwise ABSOLUTE position, it has no effect on the meter accuracy.

3-16. In all other respects, operation of a Option 02 instrument is the same as operation of a standard Model 400E/EL.

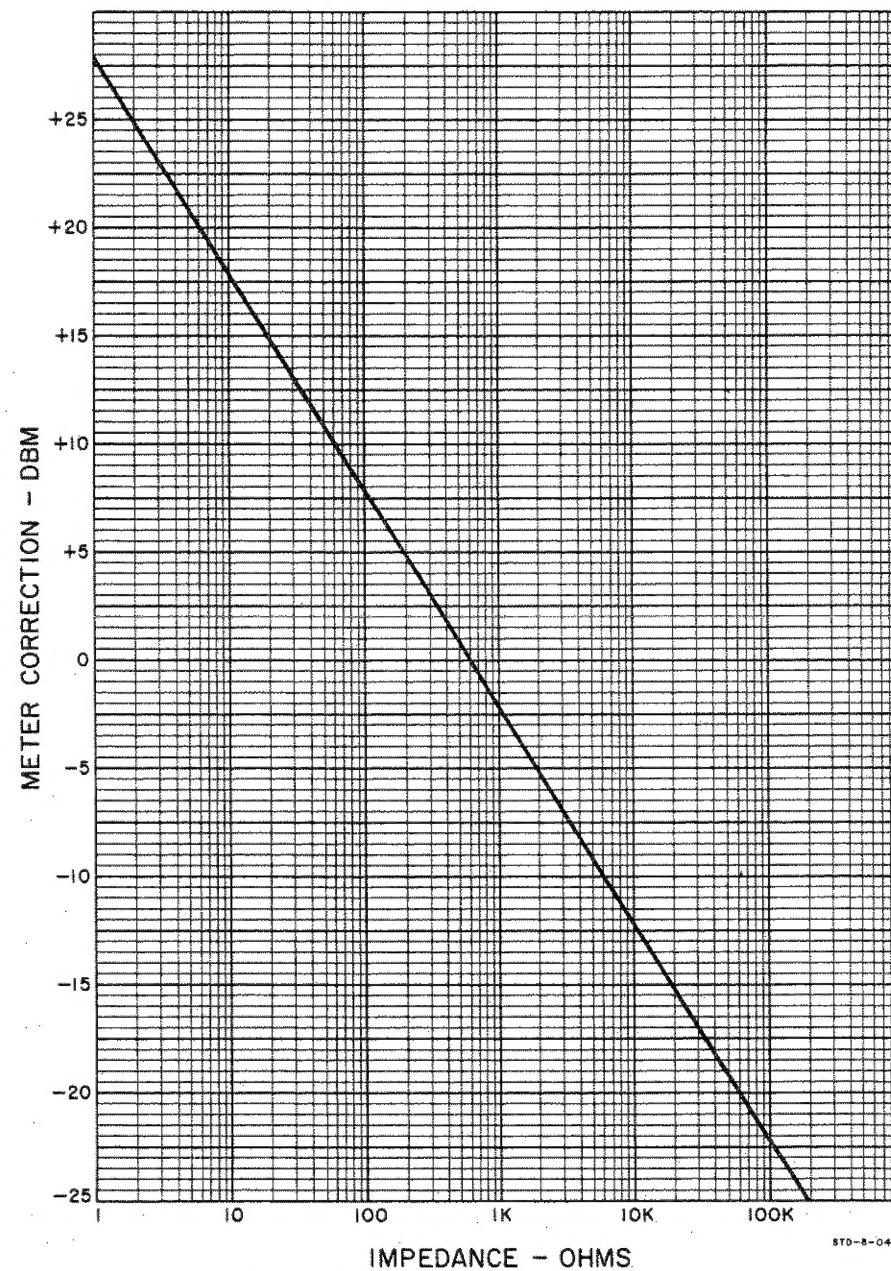


Figure 3-3. Impedance Correction Graph

## SECTION IV

### THEORY OF OPERATION

#### **4-1. GENERAL.**

4-2. The 400E/EL is a solid state, average responding, rms calibrated voltmeter. It also has applications as an ac to dc converter and a wide band amplifier. Figure 4-1 shows a simplified block diagram of the instrument.

4-3. When relay K1 is closed, the input is not attenuated; and when K2 is closed, the input is attenuated by 50dB. On the 0.001 through 1 volt ranges, K1 is closed and K2 is open. K2 is closed and K1 is open on the 3 through 300 volt range. The entire Input Attenuator assembly is shielded, and the relays are operated remotely by voltages applied through the RANGE switch. Variable capacitor A1C2 is adjusted on the 3 volt range with a 3 volt 100kHz input in order to shape the frequency response of the Input Attenuator.

4-4. The signal from the input attenuator is applied to the impedance converter. The impedance converter is a unity gain, feedback stabilized amplifier that matches the high Impedance of the Input Attenuator to the much lower impedance of the Post Attenuator.

4-5. The Post Attenuator attenuates the output of the Impedance Converter by 10dB for each step of the RANGE switch. On the 3 volt range, the Post

Attenuator is switched back to the 30dB position, and then it attenuates 10dB per step on the higher ranges. Variable capacitor S2C2 is adjusted on the .003 volt range with a 3mV, 8MHz input to adjust the 8MHz response of the .003 volt range. With a full scale input on any range except the .001 volt range, the output of the Post Attenuator should be 3mV. On the .001 volt range, the output should be 1mV.

4-6. The Meter Amplifier is a four-stage, high-gain amplifier utilizing both ac and dc feedback for gain stabilization. The Meter Bridge, connected in the ac feedback path of the meter amplifier, converts the ac output of the amplifier to a dc voltage proportional to its average value. This dc voltage drives the meter. A2C28 and A2R38 adjust the gain of the amplifier so that the meter will read rms volts. A2R38 is adjusted at 400Hz, and A2C28 is adjusted at 10MHz.

4-7. The DC Output is a 0-1 volt level that is proportional to meter deflection. R2 is adjusted to calibrate the dc output. The AC Amplifier samples the ac feedback and generates 0 to 150mV ac output that is directly proportional to meter deflection.

#### **4-8. SCHEMATIC DESCRIPTION.** (See Figure 7-1).

#### **4-9. IMPEDANCE CONVERTER.**

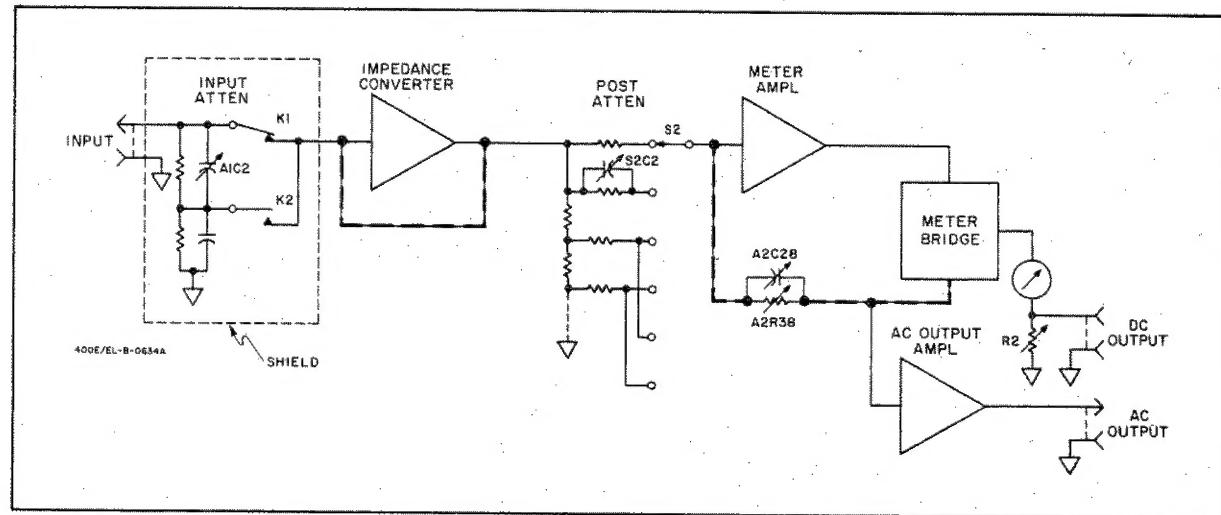


Figure 4-1. Simplified Block Diagram

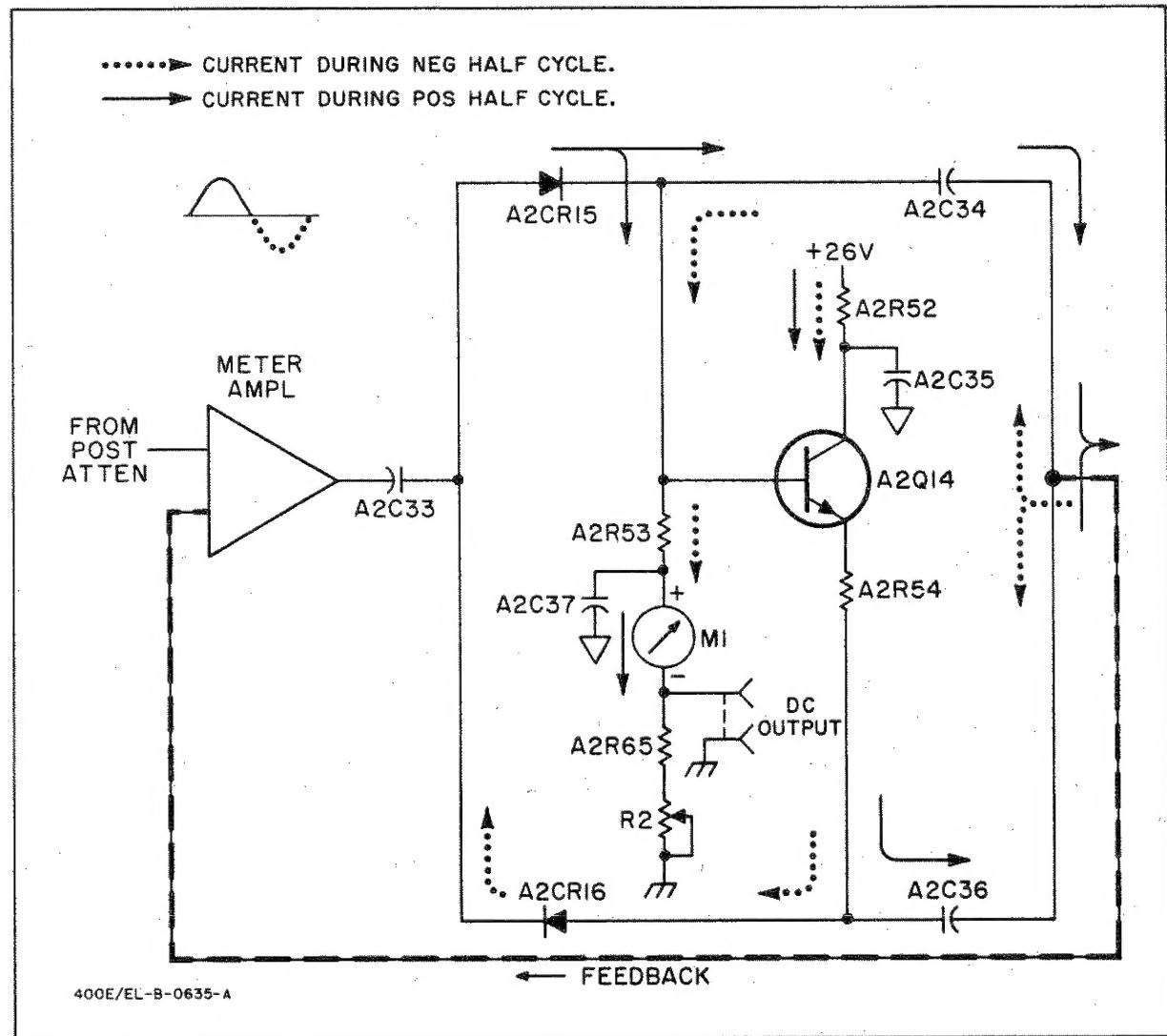


Figure 4-2. Meter Bridge

4-10. The impedance converter, located on the main voltmeter board (A2), matches the high impedance of the input attenuator to the relatively low impedance of the Post Attenuator. Breakdown diodes A2CR17 and 18 bias diodes A2CR9 and 10 at +5 and -5 volts respectively. A2CR9 and 10 limit the input to 10 volts peak-to-peak, providing overload protection. Breakdown diodes A2CR20 and A2CR21 stabilize the bias voltages on A2Q5. Fuse A2F1 protects the instrument against destructive overloads.

4-11. A field-effect transistor (A2Q5) is used in the input stage of the impedance converter because of its characteristically high input impedance and good frequency response. The output is taken from the emitter circuit of A2Q7 and applied to the post

attenuator and then applied to the meter amplifier. The solid black lines on the schematic show the signal path, and the broken lines show the feedback paths. A2R17 adjusts the dc bias of the impedance converter.

#### 4-12. METER AMPLIFIER.

4-13. The meter amplifier amplifies its input signal by a fixed gain on all ranges except the .001 volt range. The amplifier itself is a four-stage, dc coupled amplifier with a cascode-coupled final stage (A2Q12 and 13). Dc feedback is coupled from the emitter of A2Q12 back to the base of A2Q9. Breakdown diodes A2CR12, 13 and 14 establish fixed dc bias levels in the amplifier.

4-14. The output from the collector of A2Q13 is coupled through the Meter Bridge and fed back to the emitter of A2Q9. A2C28 in the feedback circuit adjusts the amount of feedback at the high end of the frequency range, and A2R38 adjusts the feedback at the low end. This calibrates the amplifier gain at both ends of the frequency range. A2R44, 45 and 72 are switched into the feedback circuit on the 0.001 volt range, boosting the gain on that range. A2R44 adjusts the gain on the 1mV range with a 400Hz input. A2R31 adjusts the dc bias level of the amplifier.

#### 4-15. METER BRIDGE.

4-16. Figure 4-2 shows a partial schematic of the Meter Bridge. The meter bridge rectifies the ac amplifier output and supplies the dc current to drive the meter. In order to use part of the meter bridge output as the rear terminal dc output, the meter has to be referenced to ground. Transistor A2Q14 references the meter to ground.

4-17. During the positive half cycle, A2CR15 conducts. Part of the current (solid line) goes through A2C34 into the feedback path, and part of the current goes through A2R53 and the meter to ground. The current through A2R53 turns on A2Q14, and A2Q14 draws current from the positive supply. The current from A2Q14 goes through A2C36 into the feedback path. The current through A2Q14 and A2C36 is equal to the current drawn through the meter, so the current out of the bridge is equal to the current into the bridge.

4-18. During the negative half cycle, A2CR16 conducts and draws current from the feedback path (dotted line). Part of the current goes through A2C36

and A2CR16 into the amplifier, and part goes through A2R53 and the meter to ground. The current through A2R53 turns on A2Q14, and the current from A2Q14 goes through A2R54 and A2CR16 to the amplifier. Again the current through the meter equals the current through A2R54, and the current into the bridge equals the current out.

4-19. Transistor A2Q14 replaces current drawn by the meter, so the meter bridge is kept floating while the meter is referenced to ground. The dc output, taken across A2R65 and R2, is also referenced to ground.

#### 4-20. AC OUTPUT CIRCUIT.

4-21. The ac output circuit isolates the meter bridge and amplifier from the ac output load. It consists of two emitter followers (A2Q15 and Q16) connected in cascade. A2R59 in the base circuit of A2Q15 zeroes the output dc level at the ac output.

#### 4-22. POWER SUPPLY.

4-23. The power supply produces regulated +26 volts and -26 volts. Breakdown diode A2CR7 establishes a reference voltage of 6.98 volts. Part of the power supply output is applied to the base of A2Q2, and A2Q2 senses the difference between the supply output and the reference. If the output voltage changes, the emitter to base voltage of A2Q2 will change; and the output of A2Q2 will change the current through A2Q1, the regulator.

4-24. The negative regulator, A2Q3 and A2Q4, uses the +26 volt output as a reference. Consequently, the negative supply is dependent upon the positive supply.